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Clinical Correlates of Surveillance Events Detected by National Healthcare Safety Network Pneumonia and Lower Respiratory Infection Definitions—Pennsylvania, 2011–2012

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Abstract

Objective—To determine the clinical diagnoses associated with National Healthcare Safety Network (NHSN) pneumonia (PNEU) or lower respiratory infection (LRI) surveillance events.

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Design—Retrospective chart review.

Setting—Eight acute care hospitals in Pennsylvania.

Patients—All patients hospitalized during 2011–2012.

Methods—Medical records were reviewed from a random sample of patients reported to NHSN to have PNEU or LRI, excluding adults with ventilator-associated PNEU. Documented clinical diagnoses corresponding temporally to the PNEU/LRI events were recorded.

Results—We reviewed 250 (30%) of 838 eligible PNEU and LRI events reported to NHSN; 29 (12%) of reported events fulfilled neither PNEU nor LRI case criteria. Differences interpreting radiology reports accounted for most misclassification. Of 81 PNEU events in adults not on mechanical ventilation, 84% had clinician-diagnosed pneumonia, of which 25% were attributed to aspiration. Of 43 adult LRI, 88% were in mechanically ventilated patients and 35% had no corresponding clinical diagnosis (infectious or non-infectious) documented at the time of LRI. Of 36 pediatric PNEU events, 72% were ventilator-associated, and 70% corresponded to a clinical pneumonia diagnosis. Of 61 pediatric LRI, 84% were in mechanically-ventilated patients, and 21% had no corresponding clinical diagnosis documented.

Conclusions—In adults not on mechanical ventilation and in children, most NHSN-defined PNEU events corresponded to compatible clinical conditions documented in the medical record. In contrast, NHSN LRI events often did not. As a result, substantial modifications to the LRI definitions were implemented in 2015.

INTRODUCTION

In a recent point-prevalence survey of healthcare-associated infections (HAIs) in the United States, HAI events fulfilling then-current National Healthcare Safety Network (NHSN) pneumonia (PNEU) and other lower respiratory infections (LRI) surveillance definitions were together the most common group of HAIs identified [1]. Although many HAI surveillance and prevention efforts for respiratory events have focused on device-associated infections, i.e., ventilator-associated pneumonia (VAP), recent data show that only 30–40% of NHSN-defined PNEU in adults are ventilator-associated [1,2,3].

In 2013, NHSN transitioned from surveillance for VAP to surveillance for ventilator-associated events because of limitations with the traditional surveillance paradigm. Notably, some of the signs and symptoms used for VAP surveillance have been argued to be both non-specific and subjective in a mechanically-ventilated patient population, therefore potentially capturing a significant proportion of patients who have non-infectious or even non-specific pulmonary conditions [4,5]; moreover, the clinical diagnosis of ventilator-associated pneumonia itself is subject to significant uncertainty [4,6,7]. Decisions to move away from VAP surveillance were due in part to these limitations: lack of specificity (and hence correlation with clinical diagnosis) with the surveillance definition and difficulties even with clinical diagnosis of ventilator-associated pneumonia [8,9].

In contrast, comparable information—particularly regarding correlation between the surveillance definition and clinical conditions—is not known for (1) NHSN surveillance definitions for PNEU in adults not receiving mechanical ventilation; (2) NHSN surveillance

definitions for PNEU in pediatric patients (whether mechanically ventilated or not); or (3) NHSN LRI definitions (for which information about receipt of mechanical ventilation is not collected by NHSN [10]). The fact that NHSN-defined PNEU in adults not receiving mechanical ventilation is one of the most common HAI types occurring nationally raises the question of whether it should be a priority for prevention and surveillance efforts. However the known limitations of surveillance for VAP in adults suggest a possibility that the events captured by surveillance definitions for other respiratory events might not represent the intended target and need an entirely new approach as well.

We sought to determine whether these other NHSN-defined respiratory events correlated well with serious clinical infections or other adverse events, with a particular focus on assessing to what extent events identified by NHSN PNEU and LRI surveillance definitions correspond to clinician-diagnosed pneumonia and lower respiratory infections.

METHODS

Throughout this paper, the abbreviation “PNEU” refers to healthcare-associated infections as identified by NHSN surveillance definitions, whereas “pneumonia” (unabbreviated) will refer to the clinical condition or a clinical diagnosis.

Inclusion criteria

All acute care hospitals in Pennsylvania conduct surveillance for each type of NHSN-defined HAI from all inpatient locations and report data to the Pennsylvania Department of Health through NHSN [11]. Data for this project were obtained from 8 short-stay acute care hospitals in 4 different counties within Pennsylvania, including children’s hospitals (n=2) and general hospitals (n=6). From each hospital, all patients reported to have PNEU or LRI during 2011 and 2012 were identified. Adult patients reported to have ventilator-associated PNEU were excluded from this project because other literature has described these NHSN events in detail [4,5,7]. Of the remaining NHSN events (i.e., LRI events in all patients, PNEU events in pediatric patients, and non-ventilator-associated PNEU events in adults), a subset were selected at random for review. It was not known from data reported to NHSN or from other sources what proportion of LRI events occurred in patients receiving mechanical ventilation.

Data collection and definitions

Medical records were reviewed by a team that included medical epidemiologists from CDC with experience in HAI surveillance and infection preventionists from CDC and the Pennsylvania Department of Health. The review encompassed all sources within the medical record including physician/provider notes, nursing notes, and nursing/respiratory therapy flowcharts. Additional assistance locating data elements in the medical records was provided by local hospital staff. Each patient record was first reviewed to confirm the presence of PNEU or LRI during the hospital admission, based on NHSN definitions in place during 2011–2012 [10]. In brief, PNEU was defined by the presence of new or worsening opacities on chest imaging accompanied by a combination of specific signs, symptoms, and laboratory findings. The reader may refer to [10] for more details. NHSN-defined LRI in 2011–2012

consisted of two specific infection types: BRON ("bronchitis, tracheobronchitis, bronchiolitis, tracheitis, without evidence of pneumonia") and LUNG ("other infections of the lower respiratory tract"). The specific criteria used to identify BRON and LUNG are listed in Figure 1. When necessary, the medical record abstraction team reviewed decisions about NHSN classification with an additional CDC subject matter expert on surveillance for PNEU.

For each NHSN PNEU or LRI event, the following information was recorded: selected underlying medical conditions (as noted by physicians), procedures performed during the week before onset of the NHSN PNEU/LRI event, findings from chest imaging (as summarized by radiology reports), results of microbiologic testing, and outcomes of hospitalization.

The clinical diagnoses recorded in the patient record that corresponded temporally with the NHSN event were also collected by the abstraction team verbatim. Both infectious and non-infectious diagnoses were recorded if the treating clinicians correlated these conditions with signs or symptoms used to fulfill the NHSN criteria (e.g., a patient with volume overload developing shortness of breath). These were considered to be the clinical diagnosis/diagnoses likely represented by the NHSN event.

Analysis

Data were collected on standardized abstraction forms and entered into a Microsoft Access 2007 database (Microsoft Corporation). The specific clinical diagnoses recorded during chart abstraction were grouped into clinical categories. Analysis was performed using SAS 9.3 (SAS Institute). Categorical variables were compared using chi-square tests and continuous with a Wilcoxon Rank-Sum test. Comparisons were considered significant if the P value was less than 0.05. In addition, ventilator-associated LRI events in adults were evaluated to determine whether they met 2013 criteria for NHSN ventilator-associated events [12].

Human Subjects

This project was designated as a non-research quality improvement activity after human subjects review at CDC and the Pennsylvania Department of Health. Participating institutions obtained approvals as IRB-exempt research studies (2 institutions) or non-research projects (6 institutions).

RESULTS

Overall description

During 2011–2012, the 8 participating hospitals reported 838 NHSN events eligible for inclusion in this project: 589 in adult patients and 249 in pediatric patients. Of these, 250 (29.8%) were reviewed: 149 (25%) of the reported adult events and 101 (41%) of the reported pediatric events.

Description of adult PNEU and LRI events

In adult patients, 96 NHSN PNEU events in patients not receiving mechanical ventilation and 53 LRI events underwent initial review. After chart review, 81 were confirmed to be NHSN PNEU (excluding ventilator-associated PNEU) and 43 LRI, making a total of 124 adult events reviewed in more detail. Most differences in classification related to interpretation of radiology reports.

The median age of adult patients was 67 years for both patients with LRI and patients with PNEU (Table 1). LRI events more often occurred in critical care locations (25.9% of PNEU vs. 86.0% of LRI, P<0.0001). Most of the LRI (38/43 [88.4%]) occurred in patients receiving mechanical ventilation at the time of the NHSN event. Underlying comorbidities were common among both patients with PNEU and those with LRI. However, patients with PNEU were more likely to have malignancy (48.2% of PNEU vs 20.9% of LRI, P=0.003) and to be immunocompromised (29.6% of PNEU vs 7.0% of LRI, $P \leq 0.0001$). In-hospital mortality of PNEU patients (30.9%) was higher than for LRI patients (16.3%) although this did not reach statistical significance ($P=0.08$).

The most common clinical diagnoses associated with NHSN PNEU, including events with multiple diagnoses, were healthcare-associated pneumonia and aspiration-related events (69/81 [85.2%] of PNEU). Aspiration was specifically documented as the cause in 18/69 (26.1%) of the PNEU events designated as healthcare-associated pneumonia/aspiration. In contrast, no single type of clinical diagnosis accounted for a majority of LRI events. For LRI events, healthcare-associated pneumonia/aspiration was the most commonly documented clinical diagnosis (41.9% of LRI). In addition, 40/43 (93.0%) LRI events fulfilled the NHSN BRON definition (as opposed to the LUNG definition). However, clinical diagnoses of bronchitis, tracheitis, or tracheobronchitis were uncommonly reported in these patients (7.0% of LRI).

In 34.9% of LRI and 8.6% of PNEU events ($P=0.0001$), no clinical diagnosis could be found to correspond to the NHSN PNEU or LRI event. In other words, at the time the patient fulfilled NHSN criteria for one of these definitions, the treating physicians did not document any clinical diagnosis related to changes in clinical status. None of the LRI events in patients on mechanical ventilation fulfilled 2013 NHSN criteria for ventilator-associated events.

Description of pediatric PNEU and LRI events

In pediatric patients, 35 PNEU and 66 LRI events were reviewed. After chart review, 36 were confirmed to be PNEU (due to reclassification of reported LRI events) and 61 to be LRI by NHSN criteria.

Most events reviewed (43/61 [70.5%] of LRI and 24/36 [66.7%] of PNEU) occurred in infants (Table 2). Moreover, a large proportion of both PNEU and LRI events were reported from neonatal intensive care units (63.9% and 45.9% of events, respectively). Among patients from neonatal intensive care units, median estimated gestational age at birth was 27.9 weeks (PNEU events) and 24.9 weeks (LRI events) ($P=0.02$). Most events were ventilator-associated (72.2% of PNEU and 83.6% of LRI), and occurred in patients with bronchopulmonary dysplasia or underlying chronic lung disease (52.8% of PNEU and

52.5% of LRI events). In-hospital mortality was similar for PNEU (11.1%) and LRI (11.5%).

Among the pediatric records reviewed, the most common clinical diagnosis associated with PNEU was healthcare-associated pneumonia/pneumonitis (75.6% of events, including those with multiple diagnoses). Clinical diagnoses of other respiratory infections accounted for an additional 16.7% of events. For LRI, the most common clinical diagnosis was tracheitis (41.0%), followed by healthcare-associated pneumonia/pneumonitis (13.1%), and bronchiolitis (4.9%). As in adult patients, the proportion of NHSN-defined PNEU without any relevant clinical diagnosis was small (2.8%), whereas a higher percentage of LRI (21.3%) had no clinical diagnosis documented to explain the signs/symptoms fulfilling the LRI surveillance definition (P=0.01). Most LRI events (59/61 [96.7%]) fulfilled the NHSN BRON rather than the LUNG definition.

DISCUSSION

In this sample of hospitalized patients NHSN PNEU surveillance definitions often corresponded with a clinical diagnosis of pneumonia. However, the LRI definitions performed relatively poorly, with over 30% of events in adult patients and 21% of events in pediatric patients having no documented clinical diagnosis associated with the NHSN LRI event.

The correlation between NHSN PNEU surveillance definitions and clinical diagnosis of pneumonia in adults not receiving mechanical ventilation appears to be better than what has been previously reported for VAP [4,5,7]. This might be because patients receiving mechanical ventilation are more likely to have additional medical conditions (e.g., those leading to intubation) that confound determination of healthcare-associated pneumonia by traditional surveillance definitions. These findings indicate that NHSN PNEU definitions do capture clinically significant events in adults who are not receiving mechanical ventilation.

That healthcare-associated PNEU is one of the most common HAIs occurring in hospitals in the United States [1] and most of these events are not ventilator-associated [1,2,3] suggests a high burden of clinically diagnosed healthcare-associated pneumonia among adult patients not receiving mechanical ventilation. Developing approaches to reliably identify and effectively prevent these infections could result in large reductions in acute care hospital HAIs. However, using information from radiology reports in surveillance criteria carries inherent subjectivity. Therefore, although this project did not evaluate agreement of PNEU determinations between different hospital staff, inter-rater reliability of the existing NHSN PNEU definition may be limited.

Thus, the existing NHSN PNEU definitions might be suitable for facilities to track their own progress towards prevention of healthcare-associated pneumonia in patients not receiving mechanical ventilation. Because of concerns outlined above about subjectivity, implementing non-ventilator-associated PNEU surveillance on a national level would likely require modification to surveillance definitions to remove dependence on radiographic evidence of pneumonia and to enhance the objectivity of other elements of the definitions.

Moving forward, there might be at least three potential approaches for surveillance of non-ventilator-associated PNEU. A conservative approach to definition modification would maintain the focus on pneumonia and involve limited modifications, with a goal of maintaining face validity of the PNEU definitions. Another option, similar to the approach taken with ventilator-associated events, would be to identify a combination of objective signs and laboratory results to identify healthcare-associated respiratory events of interest, which would likely not be limited to pneumonia as a result of these changes. Yet another option could be to focus on healthcare-associated respiratory events that lead to an objective endpoint, such as intubation. Both of the latter two approaches, implementing ventilator-associated event-like definitions in non-ventilated patients or conducting surveillance for unplanned, healthcare-associated intubations, are likely to decrease the correlation between surveillance definitions and specific clinical diagnoses, and further work would be needed to assess the optimal approach.

In contrast, most NHSN-defined LRI events occurred in patients receiving mechanical ventilation, and LRI events often had no corresponding clinical diagnosis. Since over 70% of patients receiving mechanical ventilation have airway colonization by microorganisms [13,14,15], the signs, symptoms, and testing results leading to identification of an NHSN LRI might not indicate the presence of an active infection but instead reflect colonization of the airways in a patient with other clinical conditions. The primary function of the NHSN LRI definition in most hospitals reporting to NHSN was to aid in determining the primary site of infection for a bloodstream infection in central line-associated bloodstream infection (CLABSI) surveillance [16]. Given the results of our project, which indicated poor correspondence between NHSN LRI and documented presence of clinical infection, attributing bloodstream infections to NHSN BRON might not be appropriate and cause underestimation of the true burden of CLABSI. For this reason, the NHSN BRON infection type was removed from surveillance protocols, starting in January 2015. As NHSN-defined LUNG infections require isolation of microorganisms from a normally sterile body site or from an invasive procedure, these were considered more likely to represent true infection and were retained.

These data also suggest potential targets for prevention activities that merit further exploration. For example, in adult patients, 26% of the PNEU events were specifically described in the medical record as attributable to aspiration. Since PNEU in non-mechanically-ventilated adults is a common healthcare-associated infection type nationally, aspiration-related PNEU may contribute significantly to healthcare-associated infection burden [1]. Activities directed towards prevention of aspiration (and perhaps targeting populations at high risk for aspiration) might be effective in reducing PNEU cases [17].

In pediatric patients, we included ventilator-associated PNEU events reported to NHSN in our medical record review since to our knowledge the performance of the NHSN PNEU definitions had not been described in this population before. Most PNEU and LRI events were identified from NICUs. In addition, unlike what has been reported overall in adult patients from other studies, most reported PNEU events were ventilator-associated. This suggests that focusing on improving definitions for ventilator-associated PNEU might be the highest priority for surveillance of respiratory infections in pediatric patients. Efforts are

ongoing to develop and test a ventilator-associated event definition for use in pediatric inpatient locations.

Clinical documentation of diagnoses might be limited as a proxy for severity as syndromes with similarly documented diagnoses could have markedly different clinical impact. However we found a high in-hospital case fatality in adult PNEU cases (particularly considering few of these patients were initially in intensive care units), supporting our conclusion that the adult PNEU events represented severe clinical conditions.

Limitations to this report include the following: first, as this was a retrospective review, we lacked a true reference standard to establish the presence of pneumonia and relied on clinical diagnoses as documented in the medical record. Second, since patients came from a convenience sample of hospitals within a single state, it is possible that PNEU and LRI events described here are not representative of those occurring elsewhere in the United States. Third, we did not attempt to identify whether there were PNEU or LRI events that met NHSN criteria but were not reported to NHSN and therefore could not include such events in our evaluation of NHSN respiratory definitions.

In summary, surveillance definitions for PNEU correspond favorably with clinical diagnosis of pneumonia in children and in adults not receiving mechanical ventilation though LRI surveillance definitions did not perform well. Before implementing NHSN PNEU surveillance on a large scale, further work to reduce subjectivity of PNEU definitions could guide efforts to identify and prevent these events and accelerate progress towards elimination of these healthcare-associated infections.

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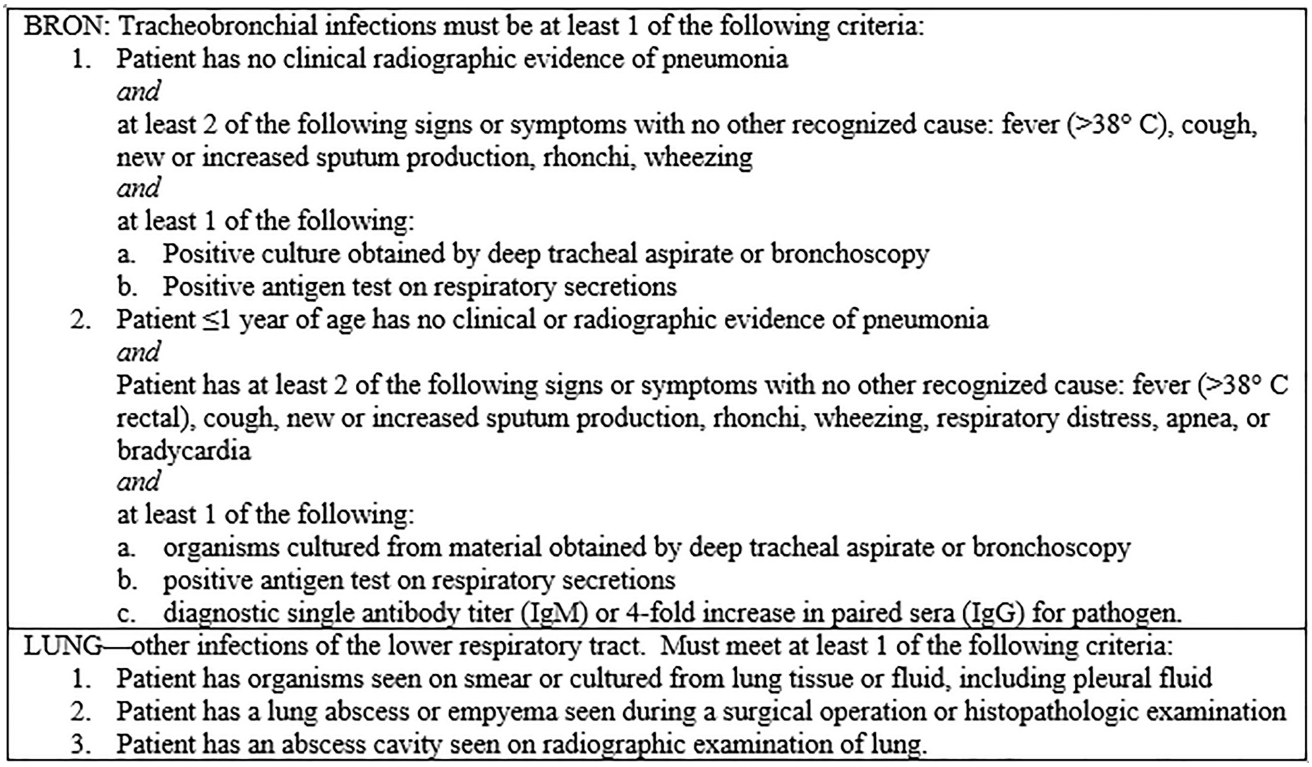

Figure 1.

National Healthcare Safety Network surveillance flow diagram for Lower Respiratory Infections (LRI) in place during 2011–2012.

Table 1

Baseline characteristics, outcomes, and clinical diagnoses of adult patients reported to the National Healthcare Safety Network to have pneumonia (PNEU), excluding ventilator-associated pneumonia) or lower respiratory infection (LRI), selected hospitals in Pennsylvania, 2011–2012.

	PNEU, no. (%) (N=81)*	LRI, no. (%) (N=43)*
Characteristics		
Age, median (range)	67 (28–93)	67 (31–88)
Occurring in critical care location	21 (25.9)	37 (86.0)
Underlying comorbidities		
Cardiac disease	28 (34.6)	27 (62.8)
Renal disease	14 (17.3)	11 (25.7)
Liver disease	8 (9.9)	1 (2.3)
Pulmonary disease	21 (25.9)	9 (20.9)
Malignancy	39 (48.2)	9 (20.9)
Immunocompromised	24 (29.6)	3 (7.0)
Outcome		
Died	25/81 (30.9)	7/43 (16.3)
Still on mechanical ventilation at discharge/transfer out of hospital (out of those who survived to discharge/transfer)	4/56 (5.6)	11/36 (30.6)
Clinical diagnoses documented ***		
ARDS	1 (1.2)	1 (2.3)
Aspiration pneumonia	13 (16.0)	2 (4.7)
COPD exacerbation	0 (0)	1 (2.3)
Empyema	0 (0)	1 (2.3)
Esophageal leak	0 (0)	1 (2.3)
Gross aspiration	4 (4.9)	2 (4.7)
Hospital-acquired pneumonia	43 (53.1)	13 (30.2)
Hemothorax	1 (1.2)	0 (0)
Respiratory infection, site not specified	0 (0)	2 (4.7)
Sepsis	3 (3.7)	1 (2.3)
Tracheobronchitis	0 (0)	3 (7.0)
Multiple **	9 (11.1)	1 (2.3)
No clinical diagnosis documented	7 (8.6)	15 (34.9)

ARDS: acute respiratory distress syndrome; COPD: chronic obstructive pulmonary disease

* All results given as no. (%) unless otherwise indicated.

** Multiple diagnoses included: both hospital-acquired pneumonia (HAP) and volume overload (4); both ARDS and HAP; HAP and diffuse alveolar hemorrhage; sepsis and volume overload; gross aspiration and ARDS; HAP and COPD exacerbation; HAP and atelectasis

*** Diagnoses for LUNG events were esophageal leak, empyema, and sepsis.

Table 2

Baseline characteristics, outcomes, and clinical diagnoses of pediatric patients reported to the National Healthcare Safety Network to have pneumonia (PNEU) or lower respiratory infection (LRI), selected hospitals in Pennsylvania, 2011–2012

	PNEU, no. (%)* (N=36)	LRI, no. (%)* (N=61)
Characteristics		
Age <1 year	24 (66.7)	43 (70.5)
Occurring in NICU	23 (63.9)	28 (45.9)
Median estimated gestational age at birth, among NICU patients	27.9	24.9
Ventilator-associated	26 (72.2)	51 (83.6)
Underlying comorbidities		
Any premature birth	23 (63.9)	34 (55.7)
Extreme prematurity	16 (44.4)	26 (42.6)
Bronchopulmonary dysplasia/chronic lung disease	19 (52.8)	32 (52.5)
Clinical diagnoses documented **		
Bronchiolitis	0 (0)	3 (4.9)
Chronic lung disease	0 (0)	2 (3.3)
Culture-negative sepsis	0 (0)	1 (1.6)
Hospital-acquired pneumonia	23 (63.9)	5 (8.2)
Infected pleural effusion	0 (0)	1 (1.6)
Pneumonitis	2 (5.6)	3 (4.9)
Possible infection	2 (5.6)	0 (0)
Respiratory infection, site not clear	4 (11.1)	3 (4.9)
Tracheitis	2 (5.6)	25 (41.0)
Upper respiratory infection	0 (0)	1 (1.6)
Multiple **	2 (5.6)	4 (6.6)
No clinical diagnosis documented	1 (2.8)	13 (21.3)
Outcome		
Died	4/36 (11.1%)	7/61 (11.5%)
Still on mechanical ventilation at discharge/transfer (out of those who survived to discharge/transfer)	8/32 (25.0)	18/54 (33.3)

NICU, neonatal intensive care unit

* All data given as No. (%) unless otherwise specified.

** LUNG events carried diagnoses of “infected pleural effusion” and “respiratory failure and pleural effusion.”

*** Multiple diagnoses included: “Respiratory failure and pleural effusion”; “Tracheitis and atelectasis”; “Tracheitis and pneumonia”; “RSV bronchiolitis and culture-negative sepsis”